

Same-sex sexual behavior in *Xenogryllus marmoratus* (Haan, 1844) (Grylloidea: Gryllidae: Eneopterinae): Observation in the wild from YouTube

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Abstract

Searching on the internet for supplementary information about species of interest can be helpful when trying to document a quite common but under studied species. While revising the genus *Xenogryllus* Bolívar, 1890, we used this method to find additional references about the species *Xenogryllus marmoratus* (Haan, 1844). We were extremely interested in one video showing an interaction between two males of this species. The video shows a small male of *X. marmoratus* mounting a larger male of the same species, and eating the product of the metanotal glands. Meanwhile, the larger male tries to transfer his spermatophore to the small one. Same-sex matings have been described in other insect species and are frequently observed in many animal groups. Most of the reported cases of same-sex sexual behavior documented in other species of insects are consistent with two causes: mistakes in sexual recognition and lack of experience. However, there are several hypotheses to explain same-sex sexual behavior that vary according to the context in which the behavior occurs. Here, we describe and discuss this video content in terms of reproductive strategies, in a context of evolution and sexual selection.

Key words

male-male sexual interactions, reproductive strategies, sexual selection

Introduction

While searching on the internet for additional references about species of interest, one can sometimes find little natural history treasures. Images from websites such as Flickr (<https://www.flickr.com/>) or Projectnoah (www.projectnoah.org) can provide rich information about the animal's distribution, in addition to high-quality pictures of our favorite animals. Similarly, sound recordings can be found in online sound libraries, even if orthopterans are usually far less covered by these databases than are birds or frogs and are difficult to identify based on sound only. A good compromise is to look for video files on popular websites such as YouTube (<http://www.youtube.com>). With video

media, it is common to get information about the location where the video was made, along with sounds and images that facilitate identification. Online videos can be particularly helpful when trying to document a species that is relatively common, but under studied. Recently, the study of such under studied species of eneopterine crickets has revealed the existence of a system of communication never reported before in crickets. This new system of communication involves high-frequency calling songs emitted by the male (Robillard and Desutter-Grandcolas 2004), absence of phonotaxis and vibrational response by the female (ter Hoftede et al. 2015). Such findings challenge the stereotyped model of communication of crickets and their mating strategies. It suggests that detailed investigations should focus on biological traits of as many species as possible in a phylogenetic context (Desutter-Grandcolas and Robillard 2004).

While revising the tribe Xenogryllini Robillard, 2004 (Jaiswara et al. in prep), we used online videos to find additional information about the species *Xenogryllus marmoratus* (Haan, 1844). This species is very common in Japan and China, where it is named Matsumushi (Japanese = pine insect) or bao ta ling (Chinese = pagoda bell), respectively. Because *X. marmoratus* is commonly observed in the field by local naturalists, it was likely to occur in the list of species that can benefit from online resources (Robillard and Tan 2013).

We found several videos where the species can be heard and/or seen, mostly from Japan, and sometimes recorded with high-quality equipment allowing us to document the details of wing movements during sound production (for example see the videos of "naturalistempus": <https://www.youtube.com/watch?v=TxlWDRbWh2Y>, or "kiokuima": <https://www.youtube.com/watch?v=kGIj7m9L7ys>). Among these interesting data, we were intrigued by one particular video showing a very uncommon interaction in the wild between two males of this species.

The mating behavior of *X. marmoratus* has not been studied in detail yet, but basic observations made in the laboratory (T. Robillard pers. obs.) suggest that its basic structure is similar to the mating behavior documented in other species of crickets (Alexander

and Otte 1967), including the eneopterine *Nisitrus* sp. (Preston-Mafham 2000): when the first spermatophore is ready to transfer, the male turns his back while raising his forewings perpendicularly to the body, which exposes the glandular structures located on the metanotum below the base of the forewings. Dorsal glands are common in males of ensiferan insects, in which the female mounts the male's back during mating (Alexander and Brown 1963, Gwynne 1984, Vahed 1998). In many species of crickets, the female feeds on the secretions from the male's metanotal glands before, during and after copulation (Boldyrev 1915, Hohorst 1937, Alexander and Otte 1967, Walker 1978, Funk 1989, Brown 1997). These kinds of nuptial feeding include the transfer of any form of nutrient from the male to the female during, or directly after, mating. The nutritional gifts are attractive for females and could represent a paternal investment: nutrients from the nuptial gift are used by the female to increase the fitness of the male's offspring (Trivers 1972, Thornhill 1976, Gwynne 1984, Vahed 1998). Also, it is known that the nuptial feeding can increase the duration of copulation to maximize ejaculate transfer (Hohorst 1937, Bidochka and Snedden 1985).

As mentioned above, the video content studied here shows an interaction between two males of the same species, and includes glandular feeding by one of the males. Same-sex sexual behavior is widespread among animals and it has been reported in most insect orders (Bagemihl 1999). In many cases, this sexual behavior is a by-product of other reproductive strategies, which are positively correlated to fitness (Bailey and Zuk 2009, Han and Brooks 2015). However, the causes, consequences and evolution of this behavior are still unknown in most groups. In this short communication, we describe the video content and discuss the implications of the observed behavioral interactions in terms of reproductive strategies.

Materials and methods

The video content analyzed here was recorded in Japan, in the prefecture of Yamaguchi in Hofu, by the YouTube user "kiokuima", and added on the public website YouTube on 20 October 2014, under the address <https://www.youtube.com/watch?v=C9hF0Fu5A64> (Kiokuima 2014). It was retrieved by typing the key word *Xenogryllus* in the search window. The author of the video is an experienced naturalist who has been posting videos of Japanese fauna since 2011. The video content is cited here as a reference and remains the property of its author.

The video was extracted for study using the online application Fluvore (<http://www.fluvore.com/>). Screenshots of the behavioral interactions were extracted from the video using Windows Movie Maker Version 2012 (Microsoft) (Fig. 1).

Results

The video lasts 6:08 min and consists of several takes fused together. It was recorded at night in the field. The songs of several species of orthopterans can be heard in the background noise, including calls of *X. marmoratus* (at least two distinct males).

Behavioral description.— 0:00–0:54 min. – A male of *X. marmoratus* is sitting on dry herbaceous vegetation (Fig. 1A). It turns around, stops, then walks left out of the frame, while moving the antennae.

0:54–1:12 min. – Same male, seen from above, motionless on plant stems.

1:12 min. – Male raises its wings perpendicularly to the body, adopting the usual mating position and exhibiting the metanotal glands (Fig. 1B).

1:20 min. – Another cricket's antennae clearly appear at the male's back (Fig. 1B, red circle). Both individuals' antennae briefly touch each other, causing a subtle startle of the first male's body (1:26), but it keeps its forewings raised. The second cricket slowly approaches from behind (Fig. 1C).

1:37 min. – The second individual puts one leg on the back of the first one (red circle on Fig. 1D). At this point, the viewer is prepared to observe a mating sequence, but when the second individual moves forward on the first individual's back, it becomes clear that this is not a female, but a second male of *X. marmoratus* (Fig. 1E) (hereafter male 2).

1:37–1:48 min. – Male 2 mounts the back of male 1 up to the exposed metanotal glands (Fig. 1F).

1:48–3:07 min. – Male 2 feeds on the glands of male 1 (Fig. 1F–G), even pushing forward male 1's forewings with its head.

3:08 min. – Male 1 reacts by moving the whole body, then becomes still again while male 2 continues feeding on its glands.

4:10 min. – Slightly different angle, probably shortly after. Male 2 is still eating from male 1's glands but the latter moves, as if trying to remove male 2 from its back (Fig. 1H).

4:24 min. – The intentions of male 1 become clearer as the apex of its abdomen enters the frame of the video: its genitalia are raised and a spermatophore is ready to be transferred (Fig. 1I). Male 1 attempts mating with male 2.

4:45 min. – Slightly different angle, probably shortly after. This angle shows that male 2 is clearly shorter than male 1, as it is entirely sitting on the abdomen of male 1 (Fig. 1J). Both males are motionless, but male 2 continues feeding on male 1's glands.

5:20–6:08 min. – Multiple new attempts at mating. Male 1 repeatedly bends its abdomen apex dorsally, but fails to reach male 2, which calmly continues feeding on the other's glands (Fig. 1J).

Discussion

The video clearly shows a small male of *X. marmoratus* mounting a larger male of the same species, and eating the product of the metanotal glands. Meanwhile, the larger male tries to transfer his spermatophore to the small one. The hypothesis that males of two sympatric species, a large one and a smaller, may be interacting in the video can be discarded for several reasons: first, the acoustic background of the video lets us hear only the song of *X. marmoratus* and no other song that could be due to another species of this genus. Second, we believe that, if there was a new species of large cricket in Japan, it would have been described long ago by local taxonomists. Third, the ongoing revision of *Xenogryllus* led us to examine many *Xenogryllus* specimens from Japan from several collections of natural history museums; this study suggests that *X. marmoratus* is the only species of the genus distributed in Japan (T. Robillard pers. obs.; Jaiswara et al. in prep.).

The fact that the video content was obtained from YouTube might call into question its authenticity. It is obviously the result of video editing from several video takes, which means that the overall timing could not be completely trusted. However, it is clear that the same insects have been filmed in the wild more or less continuously, according to the acoustic background and the similarity of the vegetation visible during the whole sequence. The longevity and high-quality of activity of the author on his YouTube channel (ca. 650 followers) dedicated to the fauna of Japan attests to the reliability of his videos and precludes the possibility that this video could be faked. Consequently, even if this video should be treated with caution, the rarity of observations of same-sex mating in the wild deems this video worthy of discussion here.

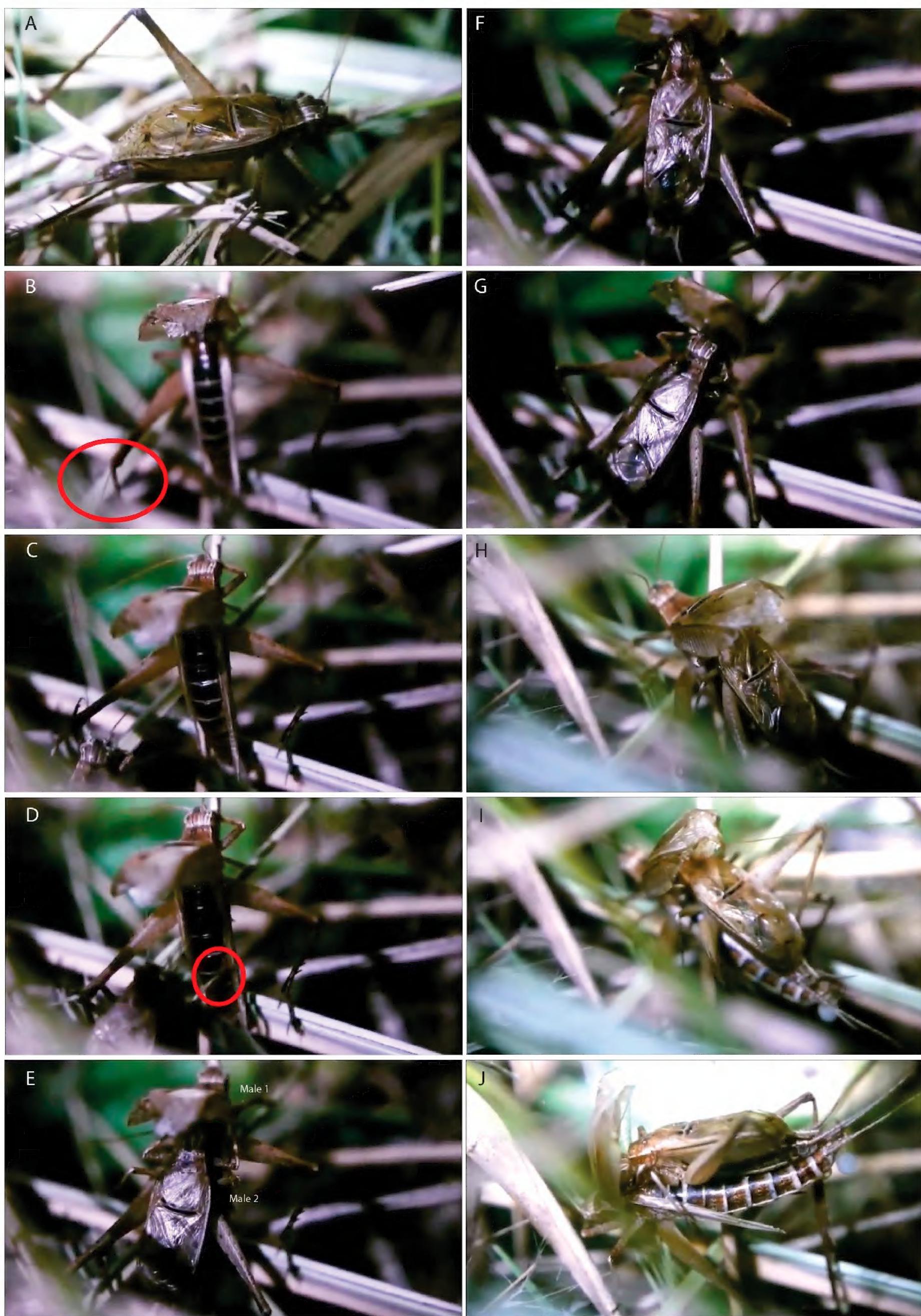


Figure 1. Screenshots of the video showing same-sex sexual behavior between males of *Xenogryllus marmoratus* (Haan, 1844). For details, see the results section.

Same-sex matings are frequently observed in many animal groups (Thornhill and Alcock 1983, Maklakov and Bonduriansky 2009) and have been described in other insect species, for example in *Drosophila melanogaster* (McRobert and Tompkins 1988), the weevil *Diaprepes abbreviates* (Harari et al. 2000), the damselfly *Ischnura elegans* (van Gossum et al. 2005), the seed beetle *Acanthoscelides obtectus*, the flour beetle *Tribolium castaneum* (Castro et al. 1994), and also in field crickets (Bailey and French 2012). However, in most cases, same-sex mating function is difficult to define (Vasey and Sommer 2006).

Same-sex sexual behavior is treated differently according to the context and the social environment where it occurs, such as sex-ratio, competition between males for females, mating experience of the males, etc. (Burgevin et al. 2013, Han and Brooks 2015). Therefore, there are a variety of hypotheses to explain its evolution in male insects. Genetic studies in model organisms have demonstrated that there are common patterns in the evolution of these behaviors (Bailey and Zuk 2009) and most of the reported cases of same-sex sexual behavior documented in other species of insects are consistent with two causes: 1) mistakes in sexual recognition and 2) lack of experience (Scharf and Martin 2013). The first hypothesis posits that mistakes in sexual recognition could come from errors in processing the sensorial information commonly involved in courtship (e.g. visual, acoustic, chemical signals) or because individuals resemble the opposite sex in some way (Bailey and French 2012). In some cases, males use body size to distinguish between the sexes. For example, in species of butterflies or grasshoppers in which females are larger than males, larger individuals are mounted more often, independent of their sex (Bland 1991, Solensky 2004). On the other hand, immature males of some species show absence of sex-specific characteristics (McRobert and Tompkins 1988) or phenotypes more typical of females (Ruther and Steiner 2008), which may cause interacting partners to confuse their identity (McRobert and Tompkins 1988, Bailey and French 2012). In crickets, it is known that during mating, males deposit sexual pheromones on the body of the females. These pheromones can be detected by other individuals in subsequent sexual interactions (Thomas and Simmons 2009). In the same way, in other groups of insects, female pheromones are attached to the male's cuticle during mating and those males consequently become attractive for other males (Barrows and Gordh 1978, Wendelken and Barth 1985). This could result in cases of same-sex sexual behavior by the receptive males (Wendelken and Barth 1985). On the other hand, the second hypothesis posits that the need to recognize mates successfully could cause immature individuals to attempt to mate with same-sex individuals. In this way, they would learn from unsuccessful matings to identify the opposite sex correctly (Dukas 2006).

Mistaken identification was suggested in 80% of the cases as the mechanism responsible for same-sex sexual behavior in insects (Scharf and Martin 2013). In the video, we can observe how the larger male lifts the forewings to expose its metanotal gland to the smaller male and then tries to transfer the spermatophore. From the point of view of the larger male, there is a possibility that it confuses the smaller one with a female, making plausible the hypothesis of a recognition mistake. This explanation, however, is not possible if males distinguish females based on body size, since the dimorphism is usually the contrary in crickets (females are commonly larger than males), including in *Xenogryllus* species (TR, pers. obs.).

Nevertheless, we have only one observation of the behavior in the species and we do not know the conditions or the environment in which the individuals were found. If the males here are

experiencing a male-biased sex ratio and strong scramble competition, it would be important for males to find females rapidly before another male does (Han and Brooks 2013a, b). Consequently, males could benefit from increasing the rate of mating attempts, even if they sometimes choose the wrong partners. This strategy would be less costly than missing a chance to mate with an available female (Han and Brooks 2015).

Finally, another possible explanation for this observation could be that the males are isolated and have no possibility of interacting with females. Long-term exposure to individuals of the same sex or absence of mating opportunities can be the cause of another mechanism leading to these sexual behaviors. The lack of potential mates could increase the occurrence of same-sex sexual behaviors due to learned changes in preferences. In some species, the preferences for same-sex partners after isolation from opposite sex partners can even persist after opposite sex partners are available (Field and Waite 2004, Bailey and French 2012).

From the point of view of the smaller male, which deliberately feeds on the larger male's metanotal glands, the hypothesis of recognition mistake is not permitted. This behavior could however be compared to satellite male strategy documented in field crickets (e.g. Cade 1979, Bailey 1991). Here, the smaller male would not only act as a satellite male waiting to silently intercept potential females, but could also use nutritive resources produced by the larger male and destined for females, to benefit its own reproduction.

In conclusion, we document a case of same-sex sexual behavior in the cricket species *Xenogryllus marmoratus* based on one wild observation, including courtship behaviors and even the production of the spermatophore. More data and experiments are obviously necessary to test the hypotheses raised by this observation and to understand the conditions in which these sexual behaviors occur. However, this video content offers valuable information about a sexual behavior that had not been reported before for this species, and rarely for crickets in general. This can demonstrate that casual observational data could offer important information for the analysis of unaddressed aspects of the biology. The information obtained in this work will help provide a more complete knowledge of this behavior in crickets, in the context of evolution and sexual selection.

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